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AUTOMATED READABILITY INDEX

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AEROSPACE MEDICAL RESEARCH LABORATORIES

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UNIVERSITY OF CINCINNATI

NOVEMBER 1967

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AEROSPACE MEDICAL DIVISION
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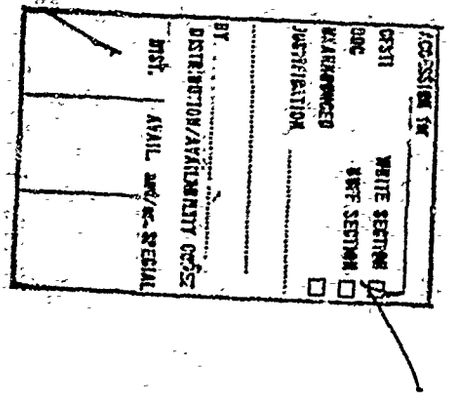

AUTOMATED READABILITY INDEX

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University of Cincinnati
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November 1967

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E. A. SMITH, EdD

AEROSPACE MEDICAL RESEARCH LABORATORIES

R. J. SENTER, PhD

UNIVERSITY OF CINCINNATI

Foreword

This study represents a portion of the exploratory development program of the Technical Training Branch of the Training Research Division. The research was conducted in part by the University of Cincinnati, under Contract AF 33(615)-1046. The work was in support of Project 1710, "Human Factors in the Design of Training Systems," Task 171007, "Automated Training and Programmed Instruction." Dr. Gordon A. Eckstrand was the Project Scientist and Dr. Ross L. Morgan was the Task Scientist. The report covers research performed between August 1964 and August 1966.

The authors are indebted to Mr. Robert J. Roettele of the Research Instrumentation Branch for the design and construction of the Tabulator.

This technical report has been reviewed and is approved.

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Abstract

Inasmuch as the utility of technical manuals is influenced to a marked extent by their reading difficulty or readability, the Automated Readability Index was devised to provide an easy, automated method of collecting data from which textual material can be evaluated in terms of readability. Whereas most readability formulae include separate factors related to (1) word difficulty and (2) sentence difficulty, the Automated Readability Index provides for the mechanical tabulation of the required data on passages as they are typed on a standard typewriter. Impulses from the typewriter activate counters which record the number of letters, words and sentences contained in the passage. From this, the average word length and average sentence length are computed. Appropriate weightings of these factors result in an index reflecting the readability of the passage. This index is in close agreement with other indices of readability.

SECTION I.

Introduction

The Air Force makes extensive use of written materials such as manuals, reports, staff studies, training documents, letters, etc. The readability of a document greatly influences the time required to extract needed information from the document. Likewise, it influences the probability that the information extracted will be correctly understood and used. The costly effects of inadequate communication are well-known. Deficiencies in written communications often could be precluded by the preparation of more readable Air Force documents. An Automated Readability Index, as described in this report, offers a fast and economical means of obtaining an index of readability of Air Force materials such as textbooks and technical manuals. Use of such an Automated Readability Index would contribute significantly to the efficiency of many Air Force operations.

Since Chall (1958) provides an excellent source, no general review of the literature will be included here. Most readability indices, however, consist of two factors. One factor relates to sentence structure and is most generally a measure of the average number of words per sentence. The other factor generally relates to word structure and is usually based on either the proportion of easy words determined with reference to word list (Dale and Chall, 1948) or the average number of syllables per word (Flesch, 1951). While the word list has many advantages, especially in the lower grades, it is both slow and relatively inaccurate when applied to adult reading material. As will be demonstrated, syllable counts prove to be deceptively unreliable.

To explore the reliability of a syllable count, a passage selected at random from a textbook was presented to a class of 65 college students. This passage contained 169 syllables. The members of the class were instructed to count the number of syllables in the passage. The group's mean syllable count was 160.56. The standard deviation of the class' syllable count was 17.52, slightly more than 10 percent of the mean. This indicates a considerable amount of variation among syllable counters, and, consequently, of any readability based on such a count. Two weeks after the initial administration of the syllable counting task, the same task was again presented to the class. A "test-retest" reliability coefficient was .38 (N=64). It would appear that both inter- and intra-judge reliability for the task of syllable counting are untenable. The development of the Automated Readability Index is an attempt to avoid this unreliability without sacrificing validity.

The Automated Readability Index is derived from ratios representing word difficulty (number of letters per word) and sentence difficulty (number of words per sentence). The data from which the index is calculated are collected through the use of an attachment to an electric typewriter. The attachment is refered to as a Readability Index Tabulator. The Tabulator is simply composed of three counters (Sodeco TCe F4E .25, TCe F5E .50, and TCe F6E .50) activated by the keyboard of the electric typewriter (IBM Selectric, model 721). These counters tabulate (a) the number of strokes, (b) the number of words, and (c) the number of sentences contained in any passage being typed. Details of the Tabulator are shown in figures 1 thru 4.

Any typist may operate this data tabulation system -- the primary modifications of standard typing procedure necessitated by the system are (1) an equal sign must be used in addition to the period at the end of each sentence, and (2) the typist must space after the terminal word in each line. During the development of the formula, these modifications were observed to be learned rather quickly and appeared to offer only minor and temporary interference with a typist's routine work.

Figure 1. Typewriter with Tabulator

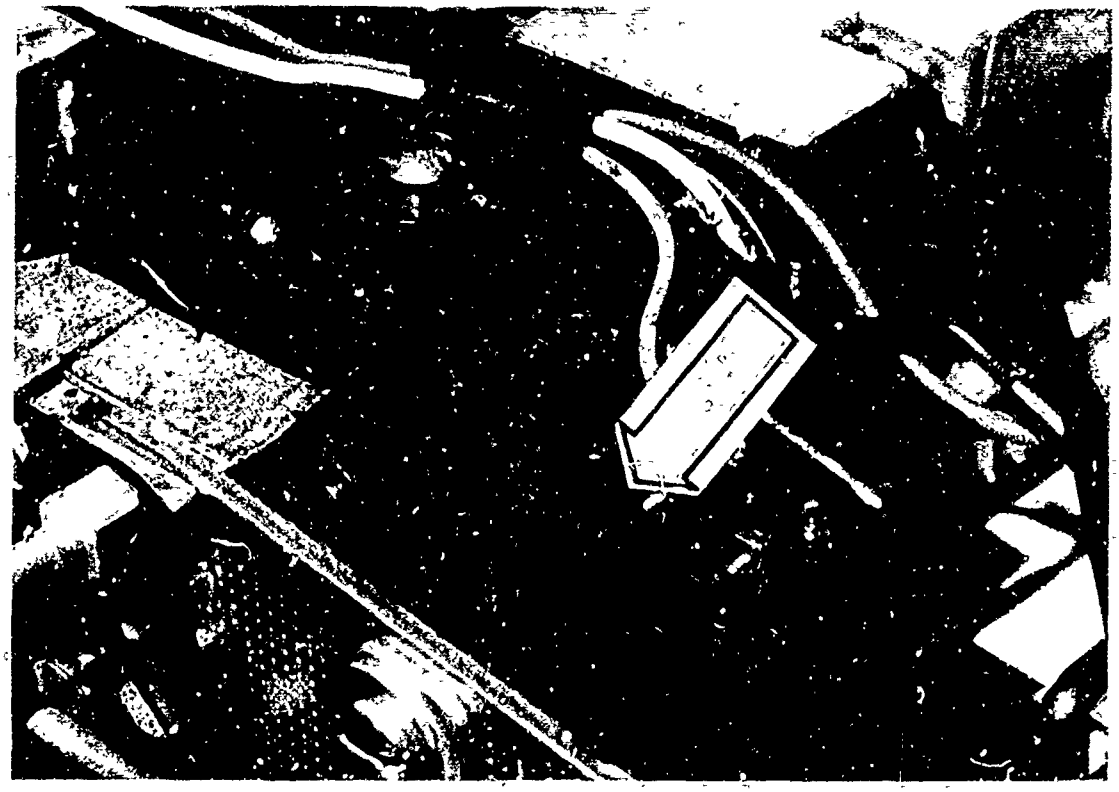


Figure 2. Pickoff for Word Count

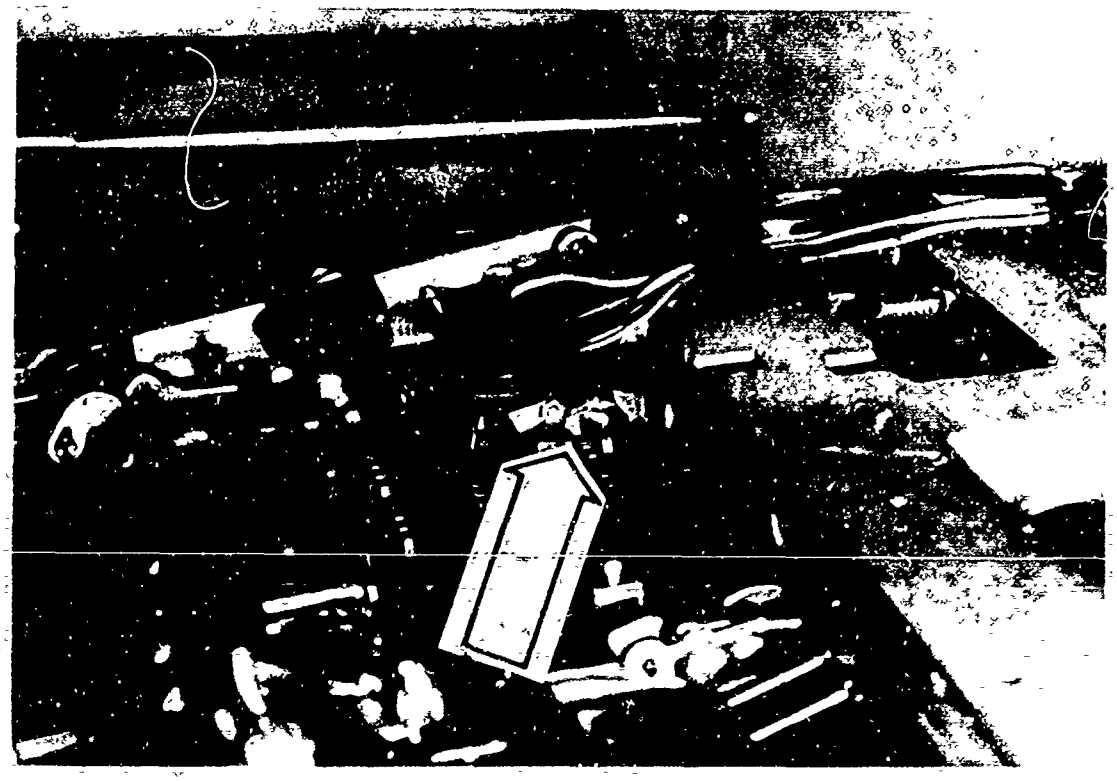
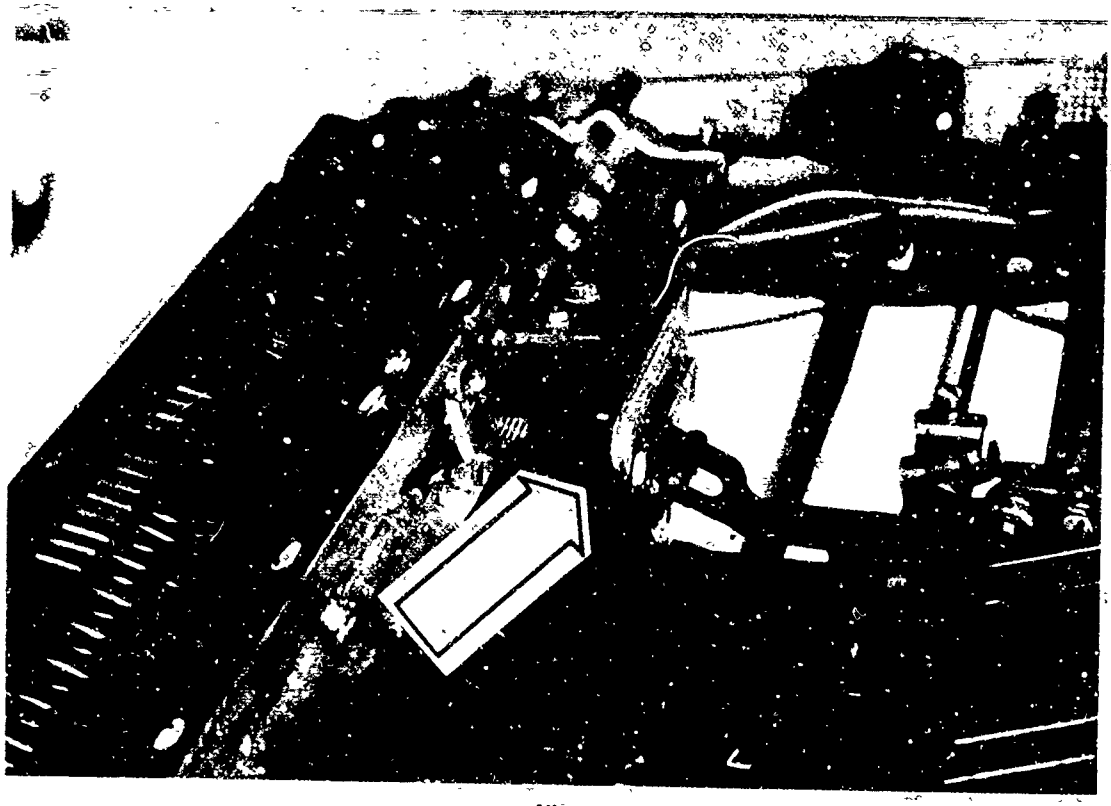
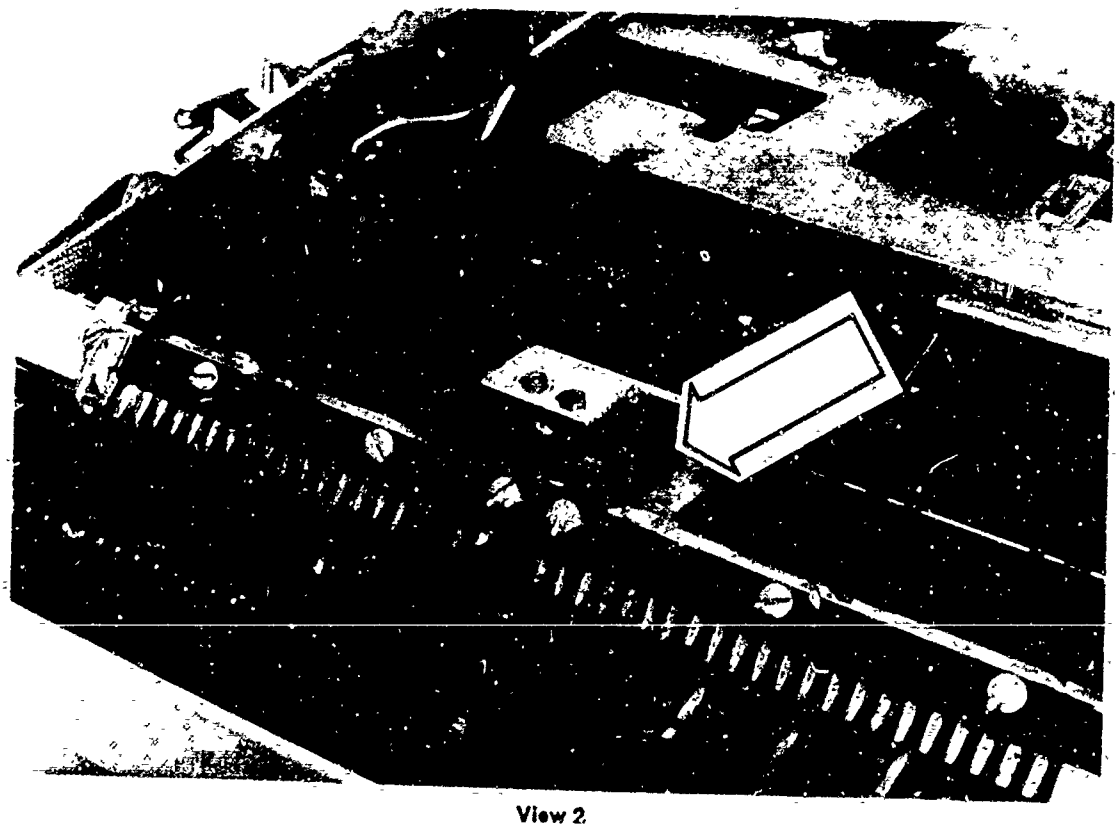


Figure 3. Pickoff for Sentence Count



View 1



View 2

Figure 4. Pickoff for Strokes Count (two views)

SECTION II.

Method

Logically, the first consideration in the development of the Automated Readability Index was to establish that the factors used relate to those found in other indices. The factor relating to sentence structure (average number of words per sentence) is identical to that found in most currently used indices so no verification of it was required. The verification of the relationship between the word structure factor was also virtually self evident. However, since the obvious is at times not accurate, formal verification was accomplished with regards to the relationship between the ratio used here (letters per word) and that employed by Flesch (syllables per word). A sample of 20 one-syllable words was selected at random from Webster's New International Dictionary. Similar samples of two-, three-, four and five-syllable words were also selected. The mean number of letters in one- through five-syllable words was 3.80, 5.50, 8.10, 10.85 and 12.25, respectively. Using the number of letters in each word as the relevant measure, student t tests were run between samples, e.g., between the sample of one-syllable and the sample of two-syllable words. The results are presented in table I. All values in table I are statistically significant at the .01 level (two-tailed tests). The words are listed in table II. The data indicate that as the number of syllables is increased, the number of letters also increases. The difference was found to be both consistent and statistically significant.

TABLE I

t-TESTS COMPARING NUMBER OF LETTERS IN WORDS OF ONE-THROUGH-FIVE SYLLABLES

Syllables	*2*	*3*	*4*	*5*
1	5.07	12.22	17.41	18.53
2		7.41	13.31	14.80
3			6.55	8.85
4				2.75

The one-syllable words in table II were obviously easier to read and found more frequently in elementary texts than the polysyllabic words.

Thus, a relationship appears to exist between the number of letters in a word and the number of syllables it contains. Also, the average number of letters per word apparently bear a fairly close relationship to the proportion of words included in a list of most common words. Therefore, the two factors used, average number of letters per word and average number of words per sentence, should provide a reasonable readability index if proper weightings for each factor are determined. Verification of the appropriateness of the factors was accomplished by correlating each factor with assigned grade level of school texts.

Determining correlations and, subsequently, the weighting to be given each factor is primarily a computational matter. There has been dissatisfaction with the derivation of some of the indices currently used. The sample of prose from which weightings were derived has often been quite small. To obtain a relatively broad base for the present computations, textbooks used in the Cin-

TABLE II

WORDS OF 1 THRU 5 SYLLABLES SELECTED AT RANDOM FROM DICTIONARY

Word	*# Syllables*	*# Letters*	*Word*	*# Syllables*	*# Letters*
an	1	2	radio	3	5
house	1	5	entering	3	8
taste	1	5	bitterly	3	8
day	1	3	calendar	3	8
dog	1	3	magazine	3	8
feel	1	4	goalkeeper	3	10
fly	1	3	injunction	3	10
we	1	2	majesty	3	7
plan	1	4	manager	3	7
run	1	3	physical	3	8
built	1	5	predicate	3	9
eel	1	3	forgery	3	7
rough	1	5	parachute	3	9
may	1	3	recapture	3	9
blast	1	5	sentiment	3	9
ease	1	4	thiamine	3	8
plant	1	5	horoscope	3	9
shape	1	5	interest	3	8
rob	1	3	mineral	3	7
sell	1	4	abdicate	3	8
any	2	3	malnutrition	4	12
daily	2	5	dictionary	4	10
supply	2	6	geriatrics	4	10
being	2	5	sentimental	4	11
settle	2	6	salutation	4	10
captain	2	7	tobacconist	4	11
because	2	7	demonstrative	4	13
into	2	4	circumference	4	13
often	2	5	formidable	4	10
player	2	6	exorbitant	4	10
enter	2	5	diagnosis	4	9
title	2	5	curriculum	4	10
carry	2	5	correspondence	4	14
filler	2	6	institution	4	11
marry	2	5	manufacture	4	11
nightly	2	7	nonconformist	4	13
candle	2	6	operation	4	9
infer	2	5	precipitate	4	11
present	2	7	primarily	4	9
happy	2	5	serenading	4	10
rudimentary	5	11	technicality	5	12
initiative	5	10	variegated	5	10
generosity	5	10	reinvestigate	5	13
circumnavigate	5	14	sanctimonious	5	13
examination	5	11	simplemindedness	5	16
disagreeable	5	12	subsidiary	5	10
corroboration	5	13	audibility	5	10
multiplication	5	14	configuration	5	13
nonperishable	5	13	fundamentalism	5	14
simplification	5	14	indefensible	5	12

cinnati Public School System were employed. To afford some comparability between grade levels, texts which were roughly analogous to *reading books* were selected. Three texts were selected at each reading level, primer through seventh grade.[1] Subject matter texts, i.e., Science, Arithmetic, etc. were deliberately excluded from the sample. It was intended that the texts be representative of the flustration as distinguished from the instructional level of reading. While these texts were obtained from only one school system, they are standard texts used throughout the country and very probably are representative of this type of text in general.

From each of these books, 20 sample pages were selected at approximately equal intervals throughout the book. At the lower levels, the entire text was used, if it totaled less than 20 full pages of text. Each sample was typed with the data recorded by use of the Tabulator.

The counters on the Tabulator are labeled (1) strokes, (2) words, and (3) sentences. The first counter (strokes) is advanced one count each time a printing key on the keyboard is struck. Printing keys include all the letters, numbers and punctuation marks. It was originally planned to eliminate the punctuation marks from this count; however, further consideration indicated that their inclusion does not make a noticeable difference in the final index. Mechanically, it is much simpler to include them.

The second counter (words) is activated each time the space bar is depressed.

The third counter (sentences) is activated by depressing the last key on the top row, i.e., the equal sign on the typewriter employed. To obtain the appropriate counts, only three minor changes from regular typing routine are required. *First*, since words are counted by counting the number of times the space bar is used, the typist must space after the last word on each line of type. *Second*, at the end of each sentence the last key on the top row must be struck in addition to the period, question mark, or exclamation point ending the sentence. Originally it was planned to use the period to count sentences, but this is impractical since not all sentences end in a period. Moreover, the period is used in many other ways, i.e., abbreviations. This would particularly invalidate a sentence count based on the use of the period. The space bar is then struck once, rather than twice. *Third*, the typist must keep in mind the purpose of her typing and adjust to "typographical errors" appropriately. She needs an accurate count of letters, spaces, and sentences but need not be concerned about spelling, indention, or proper margins. Some initial attention to spacing is often required to make certain a space is used after the last word of each line typed and also to avoid using the space bar for indentation.

DERIVATION OF FORMULA

After the sample material had been typed and the resultant tabulation counts recorded, strokes per word and words per sentence were correlated with grade levels as indicated by the publisher and Cincinnati School System as being appropriate for each of the texts. The tabulated counts from the Readability Index Tabulator were used to compute the required ratios as follows:

> *words per sentence ratio* is the result of dividing the tabulated *word* count by the tabulated *sentence* count.
>
> *strokes per word ratio* is the result of dividing the *strokes* count by the *words* count

The grade levels ranged from an assigned value of zero for the Primers through an assigned level of seven for the texts appropriate for the seventh grade. Data obtained from all 24 books

[1] Data were also obtained on texts used in grades 7 through 12. The data were not used in deriving the formula reported herein. A summary of these data is indicated in table III.

entered into the computations of the correlation with grade level. While the individual pages within a sample text were recorded for other purposes, cumulative totals throughout the sample text were used in the correlation, i.e., N=24. Limitations of the samples in failing to meet the assumptions of normalcy and continuousness required for product moment correlations must be recognized. However, it is felt that the resultant correlation, though limited, is adequate for the present purpose if properly interpreted. It will be noted that the bias injected into the data by the limited range of grade levels would tend to depress the correlations resulting in any errors associated with it being on the conservative side.

The product moment correlation between sentence length (words per sentence) and assigned grade placement was 0.96. The correlation between word length (strokes per word) and assigned grade level was 0.84. Correlation between sentence length and word length was 0.71. These correlations supported the hypothesis that the word length and sentence length ratios were related to reading level and could be utilized in a readability formula. Combining the ratios resulted in a multiple R of .98 within the texts on which the weights were based. The beta coefficient associated with sentence length was 0.72, for word length 0.33.

The multiple regression equation for predicting grade level from the two obtained ratios is

$$GL = 0.50\ (w/s) + 4.71\ (s/w) - 21.43$$

where:

GL = assigned grade level

w/s = words per sentence or sentence length

s/w = strokes per word or word length

This is simplified to

$$ARI = (w/s) + 9\ (s/w)$$

where:

ARI = Automated Readability Index

w/s = words per sentence

s/w = strokes per word

Figure 5 shows the relationship between the Automated Reading Index and the assigned grade level of the texts. There is no inversions in the relationship, i.e., in each case an increase in assigned grade level is accompanied by a corresponding increase in the Automated Readability Index.

Table III presents some of the data obtained during the investigation. Two aspects of these data merit emphasis. The first is the close correspondence between predicted and assigned grade placement is restricted to the first seven grades. The second is the close association between the ARI and Flesch Indices. Table IV indicates the derivation of the Automated Readability Index from these data. It should be noted that the weighting of the word length factor in the formula reflects the small variance of this factor. The beta coefficients provide a more realistic indication of the relative importance or contribution of the two factors. Sentence length contributes slightly more than two-thirds of the total ARI variance.

Note that the simplified formula does not result in estimated grade levels since the constant (−21.43) has been eliminated and the weightings of the two factors doubled. The resultant index is, therefore, a number associated with readability but without direct reference to a precise grade placement. This alteration was deliberate for several reasons as will be discussed below.

The derivation of the formula was based on graded readers for grades 1 through 7. Texts above the 7th grade vary in many ways other than just reading difficulty. While junior high school texts will normally have ARI's higher than those associated with the 6th grade, there will be considerable variation (see table III). This is more marked at the high school level. Again the ARI will tend to be higher than that associated with junior high texts, however, considerable varia-

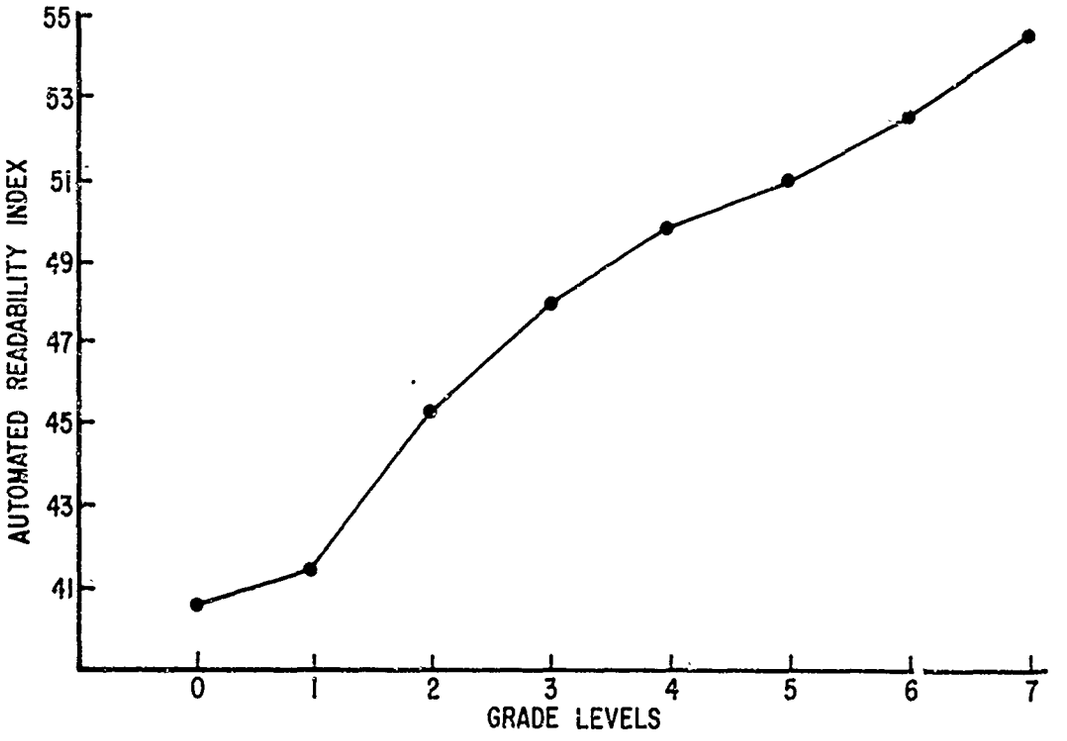


Figure 5. Relationship between Assigned Grade Level and Computed Automated Reliability Index

tion will be encountered. This is a reflection to a degree of the fact that subjects taught during the 10th year in some school systems are taught during the 11th or 12th in others. Also, within the same school system, at times a student may take a given course during any of two or three years. Thus, while it would be appropriate to suggest that the ARI indicates that in terms of readability a given text is comparable to high school texts, it would be an unjustifiable extrapolation to give a more precise designation.

Another reason for not obtaining ARI results directly in grade levels is that often such an association may be contraindicated by the circumstances. In both remedial and enrichment programs, undue emphasis on grade level equivalents may be detrimental. This is especially true of reading encountered by adults participating in in-service training programs. Perhaps more perti-

TABLE III

DATA UTILIZED IN DERIVING AUTOMATED READABILITY INDEX
(20 page samples)

	$\overline{X}$ *strokes/word*	$\overline{X}$ *words/sentence*	*ARI*[1]	*GLE*[2]	*Flesch Index*
Primer	4.12	3.51			
	4.16	4.25			
	4.23	2.65	41.00	–0.05	108
1	4.14	6.42			
	4.09	6.19			
	4.01	5.43	42.73	0.79	104
2	4.08	8.74			
	4.13	8.75			
	4.11	8.42	45.53	2.20	99
3	4.23	9.27			
	4.25	9.50			
	4.27	10.41	47.97	3.45	90
4	4.28	11.16			
	4.42	9.63			
	4.48	10.56	49.95	4.47	85
5	4.44	10.46			
	4.40	11.25			
	4.44	11.85	50.96	4.98	81
6	4.54	12.45			
	4.53	10.96			
	4.52	11.69	52.46	5.75	78
7	4.38	14.85			
	4.39	14.87			
	4.41	14.55	54.25	6.62	81
Jr. High (7, 8, 9)			54.20	6.60	77
Sr. High (10, 11, 12)			58.13	8.60	67

[1] Automated Readability Index
[2] Grade Level Equivalent based on Automated Readability Index

TABLE IV

DERIVATION OF AUTOMATED READABILITY INDEX

Variable 1 = grade level (GL)

Variable 2 = words-per-sentence (w/s)

Variable 3 = strokes-per-word (s/w)

$r_{12} = .9551$

$r_{13} = .8389$

$r_{23} = .7055$

$\sigma_1 = 2.2913$ $\quad \bar{X}_1 = 3.5000$

$\sigma_2 = 3.3075$ $\quad \bar{X}_2 = 9.4925$

$\sigma_3 = .1599$ $\quad \bar{X}_3 = 4.2938$

$$\beta_{12.3} = \frac{r_{12} - r_{13}r_{23}}{1 - r_{23}^2} = .7233$$

$$\beta_{13.2} = \frac{r_{13} - r_{12}r_{23}}{1 - r_{23}^2} = .3287$$

$$b_{12.3} = \frac{\sigma_1}{\sigma_2}\ \beta_{12.3} = .5011$$

$$b_{13.2} = \frac{\sigma_1}{\sigma_3}\ \beta_{13.2} = .4.7101$$

$$a = X_1 - (b_{12.3}X_2) - (b_{13.2}X_3) = -21.4309$$

$$GL' = .50(w/s) + 4.71(s/w) - 21.43$$

$$R_{1.23} = \sqrt{\beta_{12.3}\ r_{12} + \beta_{13.2}\ r_{13}} = .9832$$

$$\sigma^2{}_{z'} = \beta_{12.3} + \beta_{13.2} + 2\beta_{12.3}\ \beta_{13.2}\ r_{23} = .9666$$

nent is the fact that readability level is not a continuous straight line function but tapers off rapidly above seventh grade. As a result, grade level equivalents of high school, college, or technical school texts would be seriously underestimated. The index continues to increase at the upper levels, but not at a constant rate.

RELIABILITY OF INDEX

The readability of most written material varies considerably from passage to passage. As a result, the reliability of any readability index is limited by the length of the sample taken. One of the prime reasons for attempting to automate the data collection was to make it practical to take rather large samples.

During the development of this formula, twenty-page samples were taken for all books involved. This provided data suitable for investigating the reliability of smaller sample sizes. Comparing the ratios obtained from one set of five sample pages with another set of five from each of the twenty-four books used (odd-even) resulted in an estimate of what the reliability would

be if the ARI's were based on five-page samples. This estimate of reliability for five-page samples was .46 for the word length ratio and .81 for the sentence length ratio and .91 for the ARI. Although these are all statistically significant, they were judged to be lower than desired. Increasing the sample size to ten pages resulted in an estimate of reliability for word length of .87, of sentence length .92, and .95 for the ARI. These were judged to be adequate. There was no evidence to suggest that further lengthening of sample size would result in commensurate increases. As a result, it is suggested that any Automated Readability Index computed be based on a ten-page sample. At times, due to the variations among sub-sections, some precautions must be taken to select a sample that is representative of the total material to be represented by the ARI. Also, application of the formula assumes discursive, narrative material and not segmented material such as check lists, operating instructions, etc.

Note that this reliability reflects primarily variations in the written material being sampled. Reliabilities based on two consecutive tabulations of samples (test-retest) would be virtually 1.00. As a result, these reliabilities provide some indication of the optimum reliabilities that can be obtained with any formula. Even though reliabilities based on technical publications might well be higher than these based on grade school texts, estimates of readability based on smaller samples probably should be interpreted with caution.

Discussion

There are many factors involved in applying any readability index. A major consideration especially relevant when considering the adult reader is his background in the content area. If the written material is in his area of competency, readability would be less important than if it were in a subject matter area with which he had had little previous contact. Thus, a new airman may have difficulty reading a manual that is easily read by more experienced persons. An economist may be able to read most written material dealing with his speciality, yet, have difficulty reading comparatively introductory texts in electronics. Conversely, the electronics engineer might find his first encounter with a volume on economics to be difficult reading. In many ways this is similar to learning a foreign language.

Additionally, the intent of the reader is possibly the most important factor. A person reading for recreation or general interest would probably prefer books with a relatively low readability index. The same reader searching for the solution to a specific problem of concern to him might successfully undertake the reading of a much more difficult source.

Generally, the readability of a book as determined by the Automated Readability Index can only account for a portion of the factors involved in selecting appropriate written material. The background, interests and motivation of the reader and the writing style and skill of the author are possibly more important but beyond the scope of this, or any other known mathematical formula.

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13. ABSTRACT

Inasmuch as the utility of technical manuals is influenced to a marked extent by their reading difficulty or readability, the Automated Readability Index was devised to provide an easy, automated method of collecting data from which textual material can be evaluated in terms of readability. Whereas most readability formulae include separate factors related to (1) word difficulty and (2) sentence difficulty, the Automated Readability Index provides for the mechanical tabulation of the required data on passages as they are typed on a standard typewriter. Impulses from the typewriter activate counters which record the number of letters, words and sentences contained in the passage. From this, the average word length and average sentence length are computed. Appropriate weightings of these factors result in an index reflecting the readability of the passage. This index is in close agreement with other indices of readability.

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Reading						
Readability						
Training Manuals						
Writing						
Verbal Training						
Training						
Technical Data						